(12) UK Patent Application (19) GB (11) 2 137 893 A

(43) Application published 17 Oct 1984

(21) Application No 8310029

(22) Date of filing 13 Apr 1983

(71) Applicant
National Research Development Corporation (United Kingdom),
101 Newington Causeway, London SE1 6BU

(72) Inventor
Sin Yau Lin

(74) Agent and/or Address for Service
P. A. Stables, Patents Department, National Research Development Corporation, 101 Newington Causeway, London SE1 6BU

(51) INT CL^3
B29F 3/02 B01F 7/08 B29F 1/10

(52) Domestic classification
B1C 111 412 506 624 642 662 686 AU
B5A 1G5E T17J
U1S 1607 1660 B1C B5A

(56) Documents cited

GB	1591730	GB	1219800
GB	1495740	WO	80/01890
GB	1340958		

(58) Field of search
B1C

(54) **Improvements in or relating to conveying screws**

(57) A conveying screw comprises a long, cylindrical rotor 1 rotatable within a stator 2, and a propelling thread 5 is formed on the rotor and extends from one end of it to the other. At least two barrier threads 18—20 are also formed on the rotor, where they are located in axial sequence relative to each other. Each barrier thread is of wider pitch than the propelling thread 5, and each succeeding barrier thread (e.g. 19, 20) is of wider pitch than the barrier thread (e.g. 18, 19) that it succeeds, whereby the interaction of the combination of the propelling thread 5 and each succeeding barrier thread (e.g. 19, 20) exercises a stronger mixing and/or pressurising effect upon the material being conveyed than did the combination of the propelling thread with the preceding (e.g. 18, 19) barrier thread. The barrier threads (e.g. 43, 59) may be in the form of a series of aligned barrier elements separated by small gaps (54).

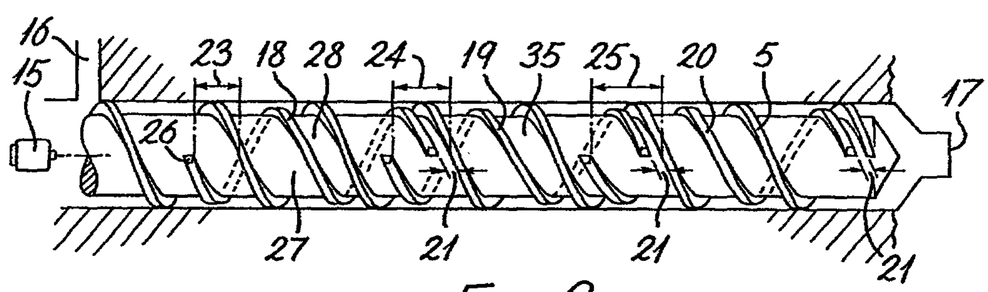


Fig. 2

GB 2 137 893 A

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

1/3

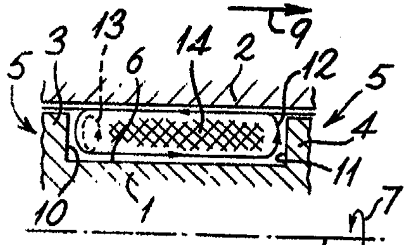


Fig. 1

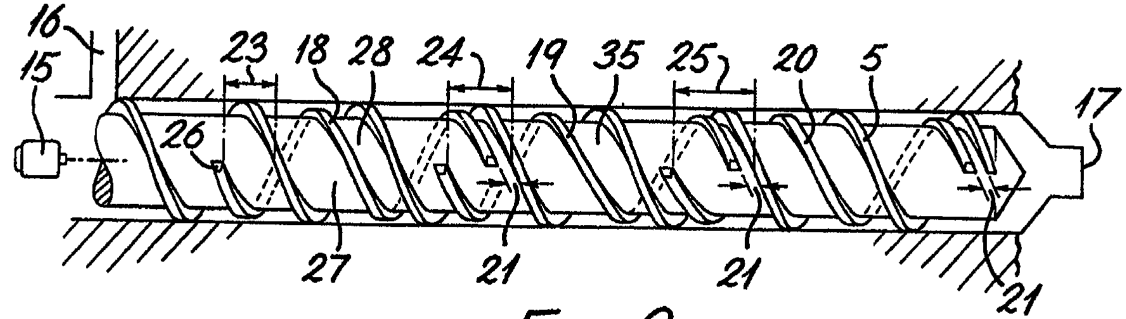


Fig. 2

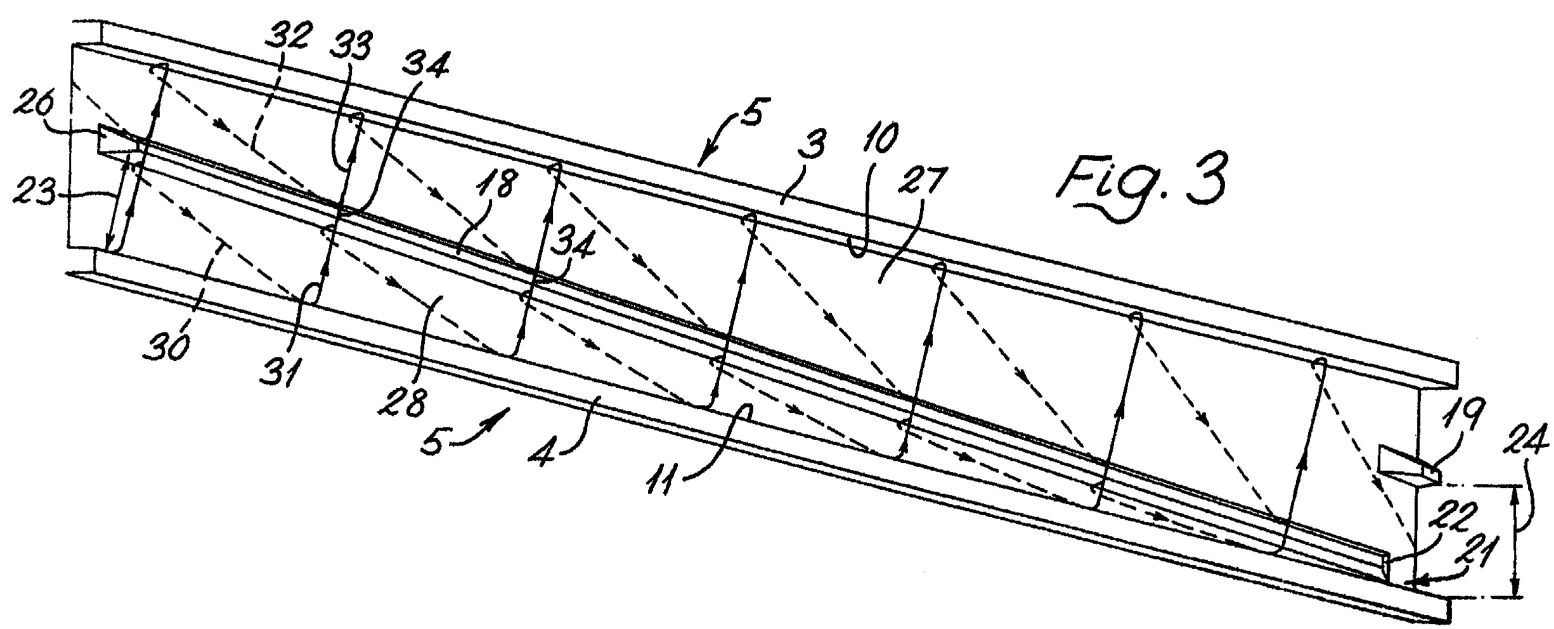
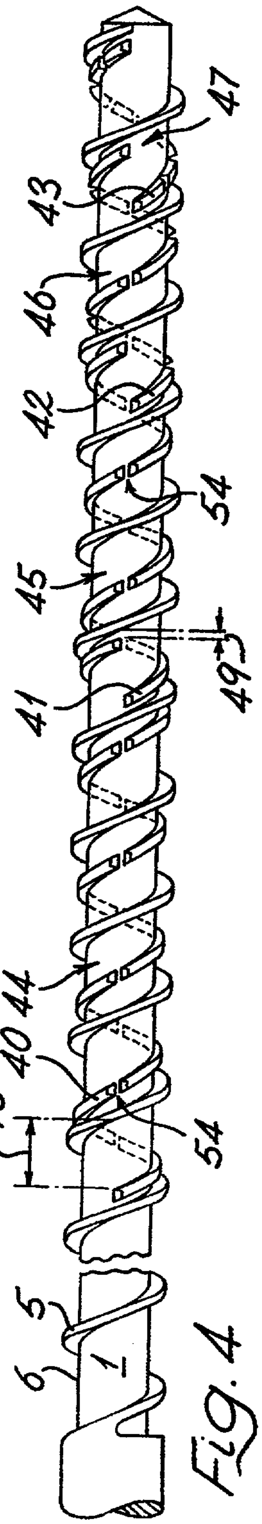


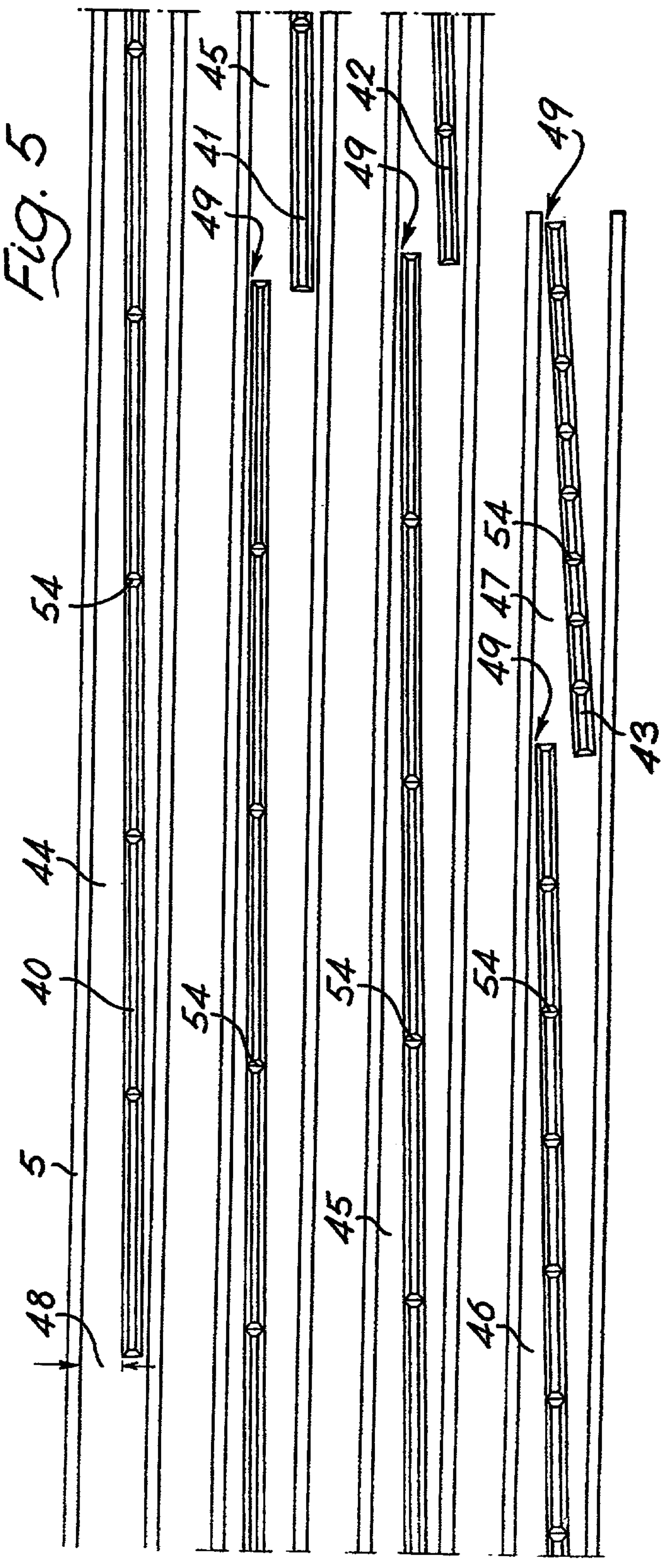
Fig. 3

2137333



47
43
46
42
54
45
49
41
44
40
48
54
5
6
1

Fig. 4



45
42
49
41
49
49
54
44
40
5
48
54
54
45
54
49
47
54
43
46

Fig. 5

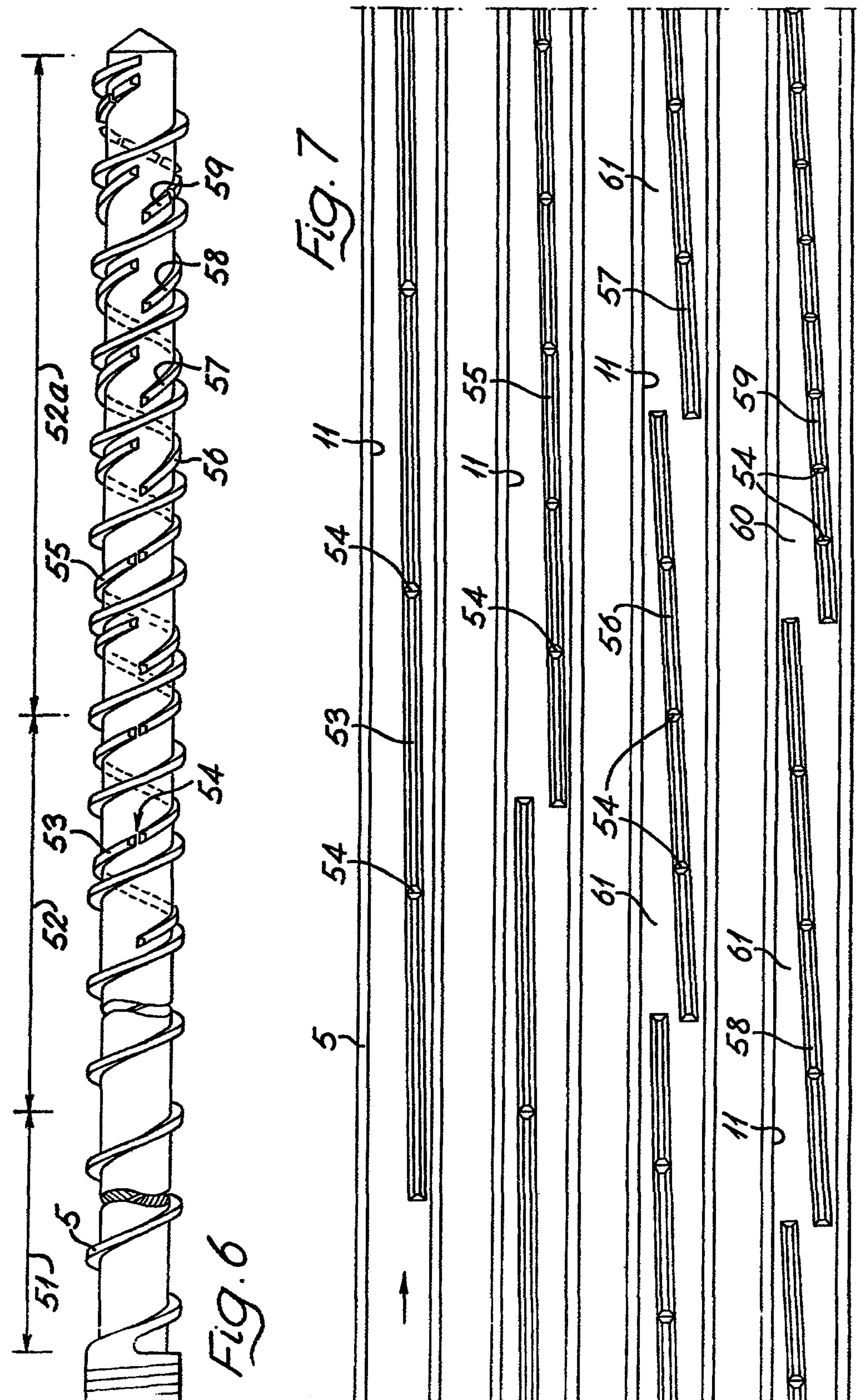


Fig. 6

Fig. 7

SPECIFICATION
Improvements in or Relating to Conveying Screws

This invention relates to conveying screws, by which I mean apparatus comprising a rotor and a stator in which the rotor carries a helical projection or rib which will be referred to as a thread. As the rotor turns, the crest of the thread generates a surfce which is separated by only a slight clearance from the surface of the stator. The surfaces of the rotor and stator are thus separated by a space of annular cross-section, containing only the thread and having a radial dimension approximately equal to the height of the thread. This space will be referred to as the screw channel. Material to be conveyed is received into this channel through an inlet at the upstream end, relative to the propelling action of the thread when the rotor is turned. When the rotor turns, reaction between the material and the forward-facing side wall of the thread pressurises the material and propels it along the channel in an axial direction, that is to say a direction parallel to the rotor axis. While the reverse arrangement is possible, usually the rotor is in the form of a rod mounted to turn within a cylindrical cavity formed within a surrounding stator. Conveying screws are used in many extruding machines, where they serve to receive raw material in granular or other fluent form into the upstream end of the screw channel, to compress and mix the material as it travels down the channel, and then to discharge the material from the machine as a solid rod of constant cross-section through an outlet formed in the stator beyond the downstream end of the channel.

As well as the overall axial propulsion already mentioned, contact with the rotor and stator also tends to mix and homogenise that material by imparting to it a second type of motion as it travels within the screw channel. This motion is illustrated by Figure 1 of the accompanying drawings, which is a radial section through part of a conventional screw extruder and shows a rotor 1 mounted to turn within its surrounding stator 2. An upstream flight or turn 3, and the succeeding downstream turn 4 of the propelling thread 5 are shown, and reference 6 indicates the surface of the body of rotor 1. Arrow 7 indicates the direction of rotation of the rotor about its axis 8, and arrow 9 indicates the overall axial direction which the rotation of thread 5 will impart to material confined in the clearance between rotor 1 and stator 2.

Figure 1 shows the approximately rectangular section of the screw channel in which the material travels between surface 6 of rotor 1, the forward face 10 of upstream screw turn 3, the rearward face 11 of downstream turn 4, and the surface of stator 2. As is customary in conveying screws, the clearance between the surface of stator 2 and the crests of thread 5 is very small, so there is negligible leakage flow through these clearances. The total flow in the channel is therefore determined by the extent of the drag flow which results from the contact between the rotor 1 and the material that fills the channel, and also a secondary drag effect resulting from contact between the moving material and the surface of stator 2. The resultant motion of the material caused by these two drag effects comprises not only a general axial motion in the direction of arrow 9, but also firstly a circulating flow around the surface of the channel and indicated by arrow 12 and secondly, in many cases, an eddy current as indicated at 13, located close to face 10 of turn 3 of the thread. Towards the centre of channel, in the region indicated by reference 14, the circulating flow is relatively slow, and material that enters this region tends to have longer residence time in the channel than material which becomes exposed to the strong circulatory motions indicated by arrows 12 and 13. Material that enters the central region 14 at the inlet to the screw channel tends to remain there over the full length of the screw, with the consequence that this material is exposed to less flow velocity, less shear and strain, and poorer heat transfer with the stator 2 (which is preset to a desired temperature), than material that becomes exposed to flows 12 and 13. This leads to poor mixing and thus inhomgeneity of of the material extruded from the outlet.

It has been proposed to inhibit the formation of the slow-moving material region 14 by mounting on the rotor one or more barrier threads in addition to the propelling thread 5. The turns of such a barrier thread or threads have been located interspersed between the turns of the popelling thread and there have in particular been proposals that the barrier threads should be less high than the propelling thread, so leaving an appreciable clearance between the barrier thread crests and the stator. It has been demonstrated that by in effect dividing the single channel of Figure 1 into two or more sections by a barrier wall the formation of a large central area of slow-moving material such as 14 is prevented, and thorough mixing of the material is promoted whenever it undergoes shear by being forced over the crests of the barrier threads. It has also been proposed that the pitch of the barrier threads should be different from that of the conveying thread with which they are interspersed.

Such proposals have however tended to be piecemeal, each being related to a single screw extruder screw comprising one particular combination of one propelling thread with one or more barrier threads. The present invention is based upon the appreciation that the efficient screw-extrusion of many materials, particularly materials calling for thorough melting and/or mixing as they pass along the screw, calls for a multi-stage device in which the relative pattern of the propelling and barrier thread changes progressively as stage succeeds stage, with corresponding change to the mixing and/or extrusion effect. According to the invention a conveying screw comprises a rotor and a co-

operating stator, at least one propelling thread formed on the rotor, and at least two stages of mixing or barrier threads also formed upon the rotor, the barrier threads being interspersed with the propelling threads but with the barrier thread stages being located in axial sequence relative to each other, each barrier thread being of wider pitch than the conveying thread with which it is interspersed, and with the barrier threads of each succeeding stage being arranged to exercise a stronger mixing and/or pressurising effect than those of the preceding stage. The threads in a succeeding stage may typically be of wider pitch than those of the preceding stage.

Successive barrier threads may be of substantially equal axial length, and may be arranged so that there is a substantially uniform axial clearance between the downstream end of each barrier thread and the downstream member of the pair of turns of the propelling thread between which that end lines, but the corresponding clearance between the upstream end of each barrier thread and the downstream member of the pair of propelling thread turns between which such upstream end is located is not constant, this clearance increasing with successive barrier threads.

Alternatively successive barrier threads may be of diminishing length, the upstream end of each such thread being separated by a large and consistent axial clearance from the downstream of the two turns of the propelling thread between which it is located, and the downstream end being separated by a small and consistent axial clearance from the downstream of the two turns of the propelling thread between which it is located.

The radial height of the propelling thread may be greater than that of any of the barrier threads, but the radial height of barrier threads other than the first may be greater than that of preceding barrier thread or threads.

Instead of being axially-continuous a barrier thread may be of interrupted form, comprising a series of aligned elements separated by small axial gaps.

The invention will now be described by way of example, with reference to the further accompanying drawings in which:—

Figure 2 shows the rotor of a conveying screw in elevation, and the stator in axial section;

Figure 3 is a developed view of part of the rotor of Figure 2;

Figure 4 shows another rotor in elevation;

Figure 5 is a developed view of part of the rotor of Figure 4;

Figure 6 shows yet another rotor in elevation, and

Figure 7 is a developed view of part of the rotor of Figure 6.

Figure 2 shows a rotor 1 which is rotatable by a motor shown diagrammatically at 15 and which is mounted within a stator 2 including an inlet 16 for raw material and an outlet 17 through which that material is discharged as an extruded product after being propelled, mixed and pressurised by the action of the rotor. As in Figure 1, the rotor carries a propelling thread 5 the crest of which is separated from the surface of rotor 2 by only an insignificant clearance. However the rotor now also carries the three barrier threads 18—20, arranged in axial sequence relative to each other but interspersed relative to the turns of the propelling thread 5. The pitch of thread 18 is wider than that of propelling thread 5, that of thread 19 is wider still and that of thread 20 is the widest of all. The spiral length of each of threads 18—20 is substantially the same, and a small axial clearance 21 between the downstream end 22 of each of them and the rearward face 11 of the adjacent downstream turn 4 of thread 5 is substantially the same. Because the three barrier threads 18—20 are of substantially the same spiral length, however, this means that the axial clearance 23—25 between the upstream ends 26 of the threads and the rearward faces 11 of the adjacent turns 4 of thread 5 are not the same: clearance 23 is the least, clearance 24 is greater and clearance 25 is greatest. The effect of having the pitch of each of barrier threads 18—20 wider than that of thread 5 is illustrated in the developed view of Figure 3, which shows the first barrier thread 18. The location of the upstream end 26 of this thread, typically from 10 to 50% of the channel width between the adjacent turns 3 and 4 of thread 5, clearly prevents the formulation of a large stagnant region of material such as is indicated at 14 in Figure 1. Instead, material passing along the channel and meeting end 26 must travel either within a diverging sub-channel 27 between the thread 18 and face 10 of turn 3, or within the converging channel 28 formed between the thread 18 and face 11: the width of channel 28 diminishes from clearance 23 at the upstream end to clearance 21 at the downstream end. The motion of the material within this converging channel is particularly significant: material flowing down it is gradually compressed and accelerated because of the narrowing width, and thus thoroughly mixed and homogenised. Lines 30—31 indicate the generally spiral path that particles of material will tend to travel as they pass down the converging channel 28, the broken lines 30 indicating those parts of the travel where the material will be moving close to the surface 6 of the rotor, and the full lines 31 those parts of the travel where it will be moving relatively close to the rotor 2. Similarly, lines 32—33 indicate the corresponding path that will tend to be taken by particles of that fraction of the material that enters diverging channel 27. It will be noticed that lines 31 and 33 are made continuous by a joining line 34. This indicates that where material is moving within channel 28 and meets thread 18 at the end of one of the legs 31 of its travel, not all of that material is turned by the side wall of that thread and then proceeds on the subsequent leg 30. Because the radial height of threads 18 is less than that of the turns of

conveying thread 5, so leaving an appreciable radial gap between the crest of the barrier thread and the surface of stator 2, some of the material passes over the crest into channel 27 at the end of each leg 31. This is beneficial to the extrusion process, because improved mixing and homogeneity of the material is promoted by the strong shearing action which the material undergoes as it is forced from channel 28 to channel 27 through the narrow clearance between the crest of the barrier thread and the surface of rotor 2.

In the second and third stages of the extruder screw shown in Figure 2, in which barrier threads 19 and 20 respectively are interspersed with propelling thread 5, the homogeneity of the material that has already been improved by the action of barrier thread 18 is improved further by the stronger action of thread 19, and then again by the yet stronger action of thread 20. The action of converging channel 34 bounded by thread 19 is stronger than that of channel 28 because its downstream end 22 is separated from the adjacent turn of thread 5 by a similar clearance 21, but the clearance 24 at the upstream end of the thread is greater than the corresponding clearance 23 of channel 28. The taper of channel 35 is therefore sharper than that of channel 28, so promoting a fiercer mixing action. Another factor promoting fiercer action in this stage than in the one preceding is the radial height of thread 19: while still less high than thread 5, this thread is higher than thread 18 so that the shearing action upon material which is forced from converging channel 35 into the adjacent diverging channel through the narrower gap between the crest of this thread and the stator is greater than that experienced by material which travelled by paths 34 across thread 18. Also, in this stage the proportion of material which enters the channel 35 at the start of the stage is greater than the proportion that entered channel 28 at the start of the preceding stage, simply because clearance 24 is greater than clearance 23. In the third and final stage of the screw shown in Figure 2 the mixing and homogenising action is greater yet again because clearance 25 is greater than clearance 24 and because the radial height of thread 20 is even greater than that of thread 19, leaving an even smaller radial clearance between barrier thread and stator through which a proportion of the material is forced from the converging to the diverging channel.

The alternative extruder screw shown in Figures 4 and 5 is in four stages instead of three, and comprises a rotor 1 formed with a continuous propelling thread 5 as before, but also with successive barrier threads 40—43. As the developed view of Figure 5 shows best, these barrier threads are so mounted on the surface of rotor 1 that the converging channels 44—47 that they form with the adjacent rearward faces 11 of the turns 4 of conveyer thread 5 all have mouths 48 of the same substantial width (practically as large as the spacing of adjacent turns of the thread 5 allows) and outlets 49 of the same small width. The increasing steepness of convergence of successive channels is now brought about by the diminishing spiral length of successive barrier threads as Figure 5 plainly shows, the developed lengths of threads 40—43 are in the ratio 5:3:2:1. It will also be noticed that threads 40—43 are not continuous, but are formed at intervals with short interruptions 54: these interruptions, provided they are short enough not seriously to affect the essential "barrier" action of the threads which cause the spiral action (lines 30—31 and 32—33) in the channels to either side of the barrier thread, provides further useful gaps and shape surfaces that the material may pass through and make impact with, so undergoing useful shearing action. Although Figure 4 does not show this feature as clearly as Figure 2 did, there is preferably also a progressive change in radial height between barrier 40 (least) and barrier 43 (greatest).

The rotor of the more complex extruder screw of Figures 6 and 7 is in three axially-separated sections 51, 52 and 52a. In the upstream section 51 the rotor carries only the propelling thread 5 and no barrier threads at all. In use this section of the rotor will be close to the inlet 16 and will act as a "feed" section to receive raw material and secure it within the turns of thread 5, without subjecting it to any significant mixing or increase of pressure. In the succeeding "compression" stage 52, containing a barrier thread also, melting, pressure and mixing action are increased progressively. The barrier thread 53 has three complete turns and is divided into six aligned elements by five interruptions 54. It overlaps into the beginning of stage 52a in which a "metering" action takes place and barrier thread 55 first extends over two complete turns and is divided into eight aligned elements by seven interruptions 54. These three threads 56—58 are arranged in axial sequence, each of one turn and each divided into four aligned elements by three interruptions 54. Finally barrier thread 59 spans one turn and is divided into eight aligned elements by seven interruptions 54. Although the taper of the converging channel 60 bounded by thread 59 is the same as that of the channel 61 bounded by each of threads 56—58, the mixing/pressurising action of thread 59 tends to be greater than that of the others because of the greater number of interruptions formed within it. Also, as indicated in connection with Figures 2, there may be a progressive increase of radial height from barrier thread 53 (least) to thread 59 (greatest).

CLAIMS

1. A conveying screw comprising a rotor and a co-operating stator, at least one propelling thread formed on the rotor, and at least two stages of mixing or barrier threads also formed upon the rotor, in which the barrier threads are interspersed with the propelling threads but in which the barrier thread stages are located in axial sequence

relative to each other, in which each barrier thread is of wider pitch than the conveying thread with which it is interspersed, and in which the barrier threads of each succeeding stage are arranged so as to exercise a stronger mixing and/or pressuring effect upon material being extruded than do those of the preceding stage.

2. A conveying screw according to Claim 1 in which the barrier threads in a succeeding stage are of wider pitch that those of the preceding stage.

3. A conveying screw according to Claim 1 in which the successive barrier threads are of substantially equal axial extent and are arranged so that there is substantially uniform axial clearance between the downstream end of each barrier thread and the downstream member of the pair of turns of the propelling thread between which that end lies, but in which the corresponding clearance between the upstream end of each barrier thread and the downstream member of the pair of propelling thread turns between which such upstream end is located is not constant, this clearance increasing with successive barrier threads.

4. A conveying screw according to Claim 1 in which successive barrier threads are of diminishing length, the upstream end of each such thread being separated by a large and consistent axial clearance from the downstream of the two turns of the propelling thread between which it is located, and the downstream being separated by a small and consistent axial clearance from the downstream of the two turns of the propelling thread between which it is located.

5. A conveying screw according to any of the preceding claims in which the radial height of the propelling thread is greater than that of any of the barrier threads, but in which the radial height of barrier threads in any stage other than the first is greater than that of the barrier threads in the preceding stage.

6. A conveying screw according to Claim 1 in which at least one barrier thread is of interrupted form and comprises a series of aligned barrier thread elements separated by small gaps.

7. A conveying screw according to Claim 1, substantially as described with reference to the accompanying drawings.

Printed in the United Kingdom for Her Majesty's Stationery Office, Demand No. 8818935, 10/1984. Contractor's Code No. 6378.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.